V. WATER CONSERVATION MEASURES AND SUPPLY ALTERNATIVES

WATER CONSERVATION MEASURES

Water conservation, also called demand management, refers to water use practices and technologies which provide the services desired by the users while using less water. The water conservation measures discussed in this section achieve long-term permanent reductions in water use. This separates them from the short-term water conservation measures and cutbacks that are required of users during water shortage situations or when short-term problems with the capacity of supply systems occur. Because of their short-term emergency nature, water shortage reductions rely almost exclusively on behavioral changes by the users (e.g., skipping or rescheduling lawn watering and taking shorter showers). Water conservation, on the other hand, generally requires changes in water use systems and technology, and little behavioral change.

The water use reductions resulting from conservation provided a basis for adjusting historical rates and patterns of water use in the modeling of the LWC Planning Document. The 2010 modeling scenarios included the water conservation measures that have been incorporated in the District's water use permit rules. The cost effectiveness of these measures are discussed in Appendix I.

Mandatory Water Conservation Measures

In District water use permitting rule amendments adopted in October 1992, specific water conservation requirements were imposed on potable water utilities (and associated local governments), on commercial/industrial users, on landscape and golf course users, and on agricultural users. All of these requirements apply to users required to obtain individual water use permits. Water use (consumptive use) permitting is further discussed in Chapter II.

Water Utilities

A conservation plan incorporating the mandatory measures is required of water utilities as a condition of permit issuance or renewal. The required conservation measures are: (a) adoption of an irrigation hours ordinance, (b) adoption of a Xeriscape landscape ordinance, (c) adoption of an ultra-low volume fixtures ordinance, (d) adoption of a water conservation-based rate structure, (e) implementation of a leak detection and repair program, (f) adoption of a rain sensor device ordinance, (g) implementation of a water conservation public education program, and (h) an analysis of reclaimed water feasibility.

Adoption of an Irrigation Hours Ordinance. The irrigation ordinance is defined as a permanent ordinance restricting urban landscape irrigation to the hours of 4:00 P.M. to 10:00 A.M. The restricted hours do not apply to hand watering with a self-cancelling nozzle, low volume irrigation systems, irrigation systems whose sole source is treated wastewater or seawater, or to operations for the purpose of system repair or maintenance.

This option will affect irrigators who do not already water between the hours of 4:00 P.M. and 10:00 A.M. It is assumed that most urban landscape irrigation already takes place during acceptable hours.

Irrigation during daytime hours is generally less efficient. The sunlight and increased winds during the restricted daytime hours cause some of the water to evaporate before hitting the ground or to blow onto impervious surfaces such as sidewalks, roads and driveways. The wind also causes the water that reaches the plants to be more unevenly applied. For there to be reductions in water withdrawn for irrigation application, users who switch from daylight hours will need to learn that the time and frequency of irrigations can be somewhat reduced and take the appropriate actions. Public education programs can contribute to the irrigation hours ordinance by informing irrigators how they can reduce applications while still meeting the water requirements of their plants. Even if applications are not reduced, more water will reach the plants and soil when the prescribed hours are followed. When the amount of water in the soil is increased, the soil profile will saturate more quickly when rains occur, and provide recharge to the Surficial Aquifer System.

To date, an irrigation ordinance has been adopted by Lee County and the cities of Fort Myers and Sanibel.

Adoption of a Xeriscape Landscape Ordinance. Xeriscape is defined by the Florida Legislature to mean "a landscaping method that maximizes the conservation of water by the use of site-appropriate plants and an efficient watering system" (Section 373.185 F.S.). The principles of Xeriscape include planning and design, soil analysis, efficient irrigation, practical turf areas, appropriate plant selection, and mulching. The legislation requires that the water management districts establish incentive programs and provide minimum criteria for qualifying Xeriscape codes. These codes prohibit the use of invasive exotic plant species, set maximum percentages of turf and impervious surfaces, include standards for the preservation of existing native vegetation, and require a rain sensor for automatic sprinkler systems. District rules, as mandated by the legislature, require that all local governments consider a Xeriscape ordinance and that the ordinance be adopted if the local government finds that Xeriscape would be of significant benefit as a water conservation measure relative to the cost of implementation.

Because of the autonomy of the cities in the LWC Planning Area regarding landscaping regulations, individual landscape codes will have to be considered and adopted by each city, and by each county for the unincorporated areas, in order for this option to be fully implemented. To date, Cape Coral, La Belle, Sanibel and Lee County have adopted complete Xeriscape ordinances.

The Xeriscape landscape ordinance will affect new construction and landscapes undergoing renovation which require a building permit. Although the ordinance will not directly affect the majority of existing landscapes, there will be some indirect impact because of the plant materials, designs and irrigation scheduling aids used for new landscapes.

Adoption of an Ultra-Low Volume Fixture Ordinance. This option requires adoption of ultra-low volume (ULV) indoor plumbing fixtures into building codes. These standards, as contained in the District's water use permit regulations, specify that the fixtures perform as follows when the water pressure is 80 pounds per square inch (psi): toilets, a maximum of 1.6 gal/flush; shower heads, a maximum of 2.5 gal/min. flow; and faucets, a maximum of 2.0 gal/min. flow.

Building requirements apply to all new construction and major renovations. They do not require early replacement of existing fixtures. Having such an ordinance improves the stocking of the ULV devices and may also increase their use as replacements in cases in which the ordinance is not applicable. The adoption of such an ordinance by appropriate local governments is a required element of utility water conservation programs.

ULV fixtures save water by using less water to provide the services desired. Available data indicate that the performance of the systems is such that the savings per unit (per flush or per minute) will not be offset by having the users increase the number of units (number of double flushes or length of shower). Thus these permanent ongoing water savings can be obtained without any behavioral changes by the users.

Until recently, the ~~current standard~~ and practice for plumbing devices throughout South Florida was that of the low volume devices (3.5 gal/flush, 3.0 gal/min shower heads, and 2.5 gal/min faucets). These are the standards that would be in effect without the ordinance. However, over the past several years, the technology of the ULV devices has become more widely accepted. Manufacturers have also increased their capacity for the production of these devices so that they can serve large markets. Because of movement to these more conserving devices throughout the country and their inherent cost effectiveness, they are capturing a large portion of the new and replacement plumbing device market irrespective of whether an ordinance is enacted. To date, an ultra-low volume fixture ordinance has been adopted by the cities of Fort Myers, Cape Coral, Sanibel and Lee County.

Adoption of a Conservation Rate Structure. A conservation rate structure is a charging system used by utilities that includes increasing block rates, seasonal rates, quantity-based surcharges, and/or time of day pricing as means of reducing demands while providing for cost recovery. This measure is a mandatory element of the conservation plans required of all utilities. Water conservation rates are generally either (a) increasing block rates, where the marginal cost of water to the user increases in two or more steps as water use increases, or (b) seasonal pricing, where water consumed in the season of peak demand, such as from October through May, is charged a higher rate than water consumed in the off-peak season. Maddaus (1987) also lists uniform commodity rates as a conservation rate structure.

This option provides a financial incentive for users to reduce demands. Those users faced with higher rates will often achieve water conservation by implementing a number of the conservation measures discussed in this chapter. The most frequently used conservation rate structure used by utilities is increasing block rates. This rate structure generally is expected to have the largest impact on heavy irrigation users. However, the effectiveness of a block rate structure is negated when users switch to another source of water in response to increased rates.

An additional concern with regard to adoption of conservation rate structures is the impact of such structures on the ability of utilities to recover costs. In general, the demand for water has been found to be inelastic. Thus, as rates are raised to promote conservation, water use declines less than proportionally, and the total revenues to the utility increase in the short term. If conservation rates are implemented in conjunction with one or more other conservation measures, the effect of the combination of measures on utility revenues and costs cannot be determined without looking at the specific conservation program.

Approximately 50 percent (10) of the regional utilities in the LWC Planning Area have adopted a water conservation rate structure.

Adoption of a Utility Leak Detection and Repair Program. The utility leak detection and repair program affects the utility production and distribution system up to the customers' meters. It includes water auditing procedures for utilities to accurately determine unaccounted-for water, leak detection efforts to identify leak locations, and repair efforts to minimize leaks. A less than 10 percent unaccounted-for loss in the distribution system is the target maximum level for public water supply utilities. The requirement that utilities implement a leak detection program if they have unaccounted-for losses greater than 10 percent has been incorporated in District rules.

A recent phone survey (August 1993) indicates that several utilities have ongoing leak detection programs. ~~As might be expected,~~ most of those which have ongoing programs are the larger utilities. This does not mean that smaller utilities do not undertake periodic leak detection and repair programs, or that most utilities do not have acceptable levels of performance with regard to unaccounted-for losses. A major difficulty in assessing the potential savings from leak detection and repair program is that, until a thorough water audit is completed, the proportion of unaccounted-for water due to leaks is not known with the requisite degree of accuracy. Data submitted to the District by the utilities indicate that many utilities are already maintaining losses close to or below the targeted 10 percent leakage loss ratio. Therefore, the potential for water savings appears to be concentrated in a few utilities which have unaccounted-for losses above 10 percent.

Adoption of a Rain Sensor Device Ordinance. Any person installing an automatic sprinkler system is required to install a rain sensor devise or an automatic switch which will overide the irrigation cycle of the sprinkler system when adequate rainfall has occurred. Rainfall sensors are also required in the Xeriscape ordinance.

Implementation of a Water Conservation Public Education Program. Public information, as a water conservation measure, involves a series of reinforcing actions to inform citizens of opportunities to reduce water use, give reasons why they should choose to practice water conservation, and publicize the conservation options being promoted by the District, local governments and utilities. Virtually all users can be affected by public information efforts, although they are typically targeted at the uses with the broadest participation, including domestic indoor and outdoor landscaping uses.

Like the restructuring of rates, public information provides incentives which encourage users to take specific actions to reduce water use. Public information efforts can also change users' behavior and encourage them to purchase water-conserving devices and systems.

The District has developed extensive conservation information for water shortage management, public education, and school programs. Public information programs conducted by the District in the LWC Planning Area have focused on Xeriscape and water shortage conservation. Approximately 75 percent (15) of the regional utilities in the LWC Planning Area have some form of a public information program.

Analysis of Reclaimed Water Feasibility. For potable public water supply utilities who control a wastewater treatment plant, an analysis of the economic, environmental, and technical feasibility of making reclaimed water available is required. Wastewater reuse is discussed in the "Water Supply Alternatives" section of this chapter.

Commercial/Industrial Users

District regulations require that all individual commercial/industrial permit applicants submit a conservation plan. This plan must include:

a. An audit of water use,
b. Implementation of cost-effective conservation measures,
c. An employee water conservation awareness program,
d. Procedures and time frames for implementation, and
e. The feasibility of using reclaimed water.

Landscape and Golf Course Users

Landscape and golf course permittees are required to use Xeriscape landscaping principles for new projects and modifications when they find this to be of significant benefit as a conservation measure relative to its cost. They are also required to install rain sensor devices or switches, to abide by the prohibition of irrigation between the hours of 10:00 A.M. and 4:00 P.M., and analyze the feasibility of using reclaimed water. There are, however, six specific exceptions to the irrigation hours limitations in the rule which provide for protection of the landscape during stress period and help assure the proper maintenance of irrigation systems.

Agricultural Users

Citrus and container nursery permittees are required to use micro irrigation systems or other system of equivalent efficiency for new installations of irrigation systems or upon modification to existing irrigation systems. Because citrus and nurseries are among the crops expected to increase in acreage in the LWC Planning Area, this requirement will limit their future water allocations and use. The permittees are also required to analyze the feasibility of using reclaimed water.

Supplementary Water Conservation Measures

Residential and Commercial Users

Indoor Audit and Retrofit. Indoor audits provide information and services directly to households and other water users to achieve efficiency in the use of interior water-using appliances. This option generally includes inspections to locate leaks and determine if plumbing devices are operating properly, repair of minor problems, and information on conservation measures and devices. In some cases, a retrofit program will include installation of water-conserving shower heads and toilet dams.

Residential retrofit measures encourage the installation of ULV plumbing fixtures or modifications which improve the performance of existing fixtures. One possible incentive is a partial financial subsidy to increase the installation of ULV water fixtures. Another incentive, recently undertaken in Tampa, is the delivery of retrofit kits to homes. The targeting and participation in efforts such as this will generally affect only a portion of the population. Utilities and local governments can devise programs which carefully target the most cost-effective applications of these measures.

Residential retrofit programs are designed to provide essentially the same service from toilets, showerheads, and faucets as existing conventional devices but at lower water use levels. In retrofit programs, a decision needs to be made as to whether to target residences with only high water consuming fixtures (generally those built pre-1980) or to include residences with low water use fixtures (post-1980) for retrofit with ULV water use fixtures.

Another characteristic which will increase the savings and the cost effectiveness of retrofit of the earlier dwelling units (homes) is that many of these units have fewer bathrooms and fixtures per unit and per person. The larger the number of people using a retrofit device, the more cost effective and water saving the retrofit. An appropriate strategy would be to target homes with large numbers of persons per fixture for complete retrofit, and other homes for retrofit of only the most heavily used fixtures. This suggests that a particularly suitable target for retrofit programs are public restrooms and other facilities which have high use rates.

Landscape Audit and Retrofit. Landscape audits are measures that improve the efficiency of irrigation systems, and include services to determine if the irrigation system is operating properly. This may include adjustments to irrigation timers (to assure that a water-conserving schedule is being followed), head replacement (to assure that the system is providing adequate coverage and not wasting water by irrigating impervious surfaces), recalibration of the irrigation system, and installation of rainfall sensing/irrigation controlling devices.

Landscape retrofit measures provide information and incentives for users to implement physical changes to their landscapes and irrigation systems. Devices suitable for landscape retrofit include those that prevent unnecessary irrigation by detecting recent rainfall or sensing soil moisture. Rainfall detecting equipment is considerably less costly, more completely tested, reliable, and available for widespread use than soil moisture sensing equipment. It is mandated in Florida Law that all new irrigation systems have rainfall sensing devices. Although soil moisture sensing equipment is much more costly and requires more frequent maintenance, it has greater potential for reducing irrigation. Soil moisture sensing equipment will meet the needs of some large users, particularly if the landscape design and conditions are such that only one sensor is necessary and the landscape is professionally maintained. Other retrofit options include converting drought-susceptible plants to drought-tolerant plant materials, rezoning irrigation systems, mulching, and installing landscape.

Audits are generally implemented by utilities and other water management agencies, and are usually aimed at indoor water use. However, because of the large outdoor component of water use in South Florida, irrigation audits can be effective. This is particularly important due to the peaking of outdoor demand during periods of low rainfall and maximum stress on water resources. Participation in landscape audits is voluntary. Audits usually focus on single family homes, although in many situations commercial and multifamily landscapes should be included.

Water Utilities

Utility Filter Backwash Recycling. This option requires water utilities using filter systems that are cleaned by backwashing (cleaning the filter by reversing the flow of water) to allow the backwash water to settle and then be retreated. Without the backwash recycling, the water is usually disposed of into a pit from which the water seeps back into the ground.

Utility Pressure Control. Water-conserving utility pressure control measures help to reduce water usage while providing acceptable water pressures to all customers. The pressure levels should keep water-using devices working properly and provide for public health and fire safety needs. Installing pressure reduction valves, as well as interconnecting and looping utility mains, are some of the means used to equalize and, therefore, reduce overall operating pressure. Unlike the pressure reduction efforts during water shortages, which call for reductions in pressures to levels necessary to meet minimums for fire flow, these changes target reductions at locations where pressures are high within the system.

Control of pressures can save water in a number of ways. High pressures exacerbate losses of water through leaks, and increase use when the amount of water used is based on time rather than the volume of water discharged. Irrigation systems on timers are the major uses wherein the use is for set periods of time. High pressures cause increases in water application and can cause atomization of the spray, which reduces irrigation efficiency. Low pressures, however, reduce the areas covered by poorly designed sprinkler systems, and this results in stress to the uncovered areas. This may encourage users to increase irrigation time in an attempt to improve the results of the irrigation efforts.

By installing pressure reduction valves, and looping and interconnecting transmission mains, utilities are able to balance pressures throughout their systems. Assuring that multistory buildings have appropriate booster pump capacity will also alleviate the need to maintain high pressures in utility lines which service these few customers.

Wastewater Utility Infiltration Detection and Repair. Wastewater utility infiltration detection and repair includes estimation and detection efforts to quantify and locate the infiltration of ground- or surface-water into wastewater collection systems, and repair efforts to reduce the infiltration.

The problem of infiltration is important in the LWC Planning Area because some of the wastewater lines in coastal areas are located below the water table for much of the year. Reducing the infiltration of fresh ground water prevents waste by allowing the ground water to be used for other purposes. Reducing the infiltration of saline water, also, prevents waste by helping the wastewater to be more acceptable for reuse. When utilities reduce infiltration, they can often delay or avoid making additions to plant and disposal capacities.

Agricultural Users

Irrigation Audit and Improved Scheduling. The District, as well as other state and federal agencies, has actively encouraged growers to adopt irrigation management practices which conserve water. For instance, agricultural irrigation audits are carried out by the District-funded Mobile Irrigation Laboratory which operates in the LWC Planning Area. Agriculture is a major water user in the area and elsewhere in the District. Changing on-farm irrigation scheduling and water management practices will play an increasingly important role in agricultural water conservation.

Irrigation management practices and technology interact, so that for example, a change in the type of irrigation system will generally require a change in irrigation scheduling to achieve the goal of water conservation while maintaining crop yield and economic return. An additional factor in agricultural water conservation is the energy savings possible through water conservation.

The irrigation audit, improved scheduling options, and the adoption of micro irrigation systems are designed to improve the "efficiency" of irrigation water use. There are a variety of different definitions of irrigation efficiency. A report prepared by the Institute of Food and Agricultural Sciences (IFAS) at the University of Florida (Smajstrla *et al.*, 1991), identifies the following concepts of efficiency: reservoir storage efficiency, water conveyance efficiency, irrigation application efficiency, and overall irrigation efficiency, which is the product of the other three types of efficiency. In addition, this report identifies effective irrigation efficiency, which adjusts overall irrigation efficiency for water which is reused or which is restored to the original water source with no reduction in water quality.

Micro Irrigation Systems. Micro irrigation systems achieve water savings by directly applying a high percentage of water to the root zone of the crop in controlled amounts, so losses through deep percolation, drainage, etc. are reduced. In addition, application of water to areas not underlain by the root zone is limited. Installation of micro irrigation systems, or systems of equivalent efficiency, are required for new citrus and container nursery crops. Additional water savings can be achieved by promoting the installation of water-conserving irrigation systems on crops where it is not required (such as vegetables), and retrofitting irrigation systems for existing citrus and nursery crops.

Different irrigation systems achieve different levels of efficiency in delivering water to meet the water requirements of crops. The major factors affecting the efficiency of an irrigation system are system design and management. In addition to differences between individual irrigation systems, irrigation efficiency varies with "the stage of crop development, time of year, climatic conditions, and other factors" (Smajstrla *et al.*, 1991).

The percentages of crops irrigated by micro irrigation systems (drip and trickle) during 1990 is shown in Table V-1 for the portions of counties within the LWC Planning Area. There are no irrigated crops in the Monroe County Area, as it is wholly protected as part of the Everglades National Park. None of the irrigated nurseries and none of the irrigated vegetable acreage in the LWC Planning Area were identified as having micro irrigation systems.

TABLE V-1. Percentage of Crop Acreages Irrigated with Micro Irrigation Systems in 1990.

County Area	Citrus	Tropical Fruit
Lee County Area	50%	10%
Collier County Area	72%	100%
Hendry County Area	60%	0%
Charlotte County Area	100%	NA
Glades County Area	77%	NA

WATER SUPPLY ALTERNATIVES

Supply augmentation is a method of increasing available water supply, and generally includes ways to optimize wellfield locations, modify otherwise unusable water, store excess water and recover it for later use, and transport or import water. Unlike water conservation measures, which include practices that reduce both indoor and outdoor water use, water supply alternatives do not address demand reduction. Instead, as explained below, water supply alternatives identify ways to expand and diversify the supply of water available to consumers in the LWC Planning Area.

Wellfield Expansion

Expansion of an existing public water supply wellfield is usually selected by a utility when additional raw water is required. The costs related to wellfield expansion for the major aquifer systems in the LWC Planning Area are provided in Table V-2.

TABLE V-2. Estimated Well Costs for Aquifer Systems in LWC Planning Area.

Aquifer System	Drilling Cost (per well)	Equipment Cost (per well)	Engineering Cost (per well)	O&M Cost (per 1000 gal)	Energy Cost (per 1000 gal)
Surficial	$36,000	$49,000	$13,000	$.003	$.02
Intermediate (1)	35,000	49,000	13,000	.003	.024
Intermediate (2)	50,000	49,000	12,000	.003	.028
Floridan (3)	92,000	52,000	14,000	.003	.032

Notes: Intermediate (1) Northern Lee and Hendry counties; Intermediate (2) Collier and southern Lee counties; and Floridan (3) Lee county.
Source: PBS&J Water Supply Cost Estimates, 1991.

Ground water wells are limited in the amount of water they can yield by the rate of water movement in the aquifers, the rate of recharge, the storage capacity of the aquifer, environmental impacts, and proximity to sources of contamination by saltwater intrusion or poor quality ground water. These factors together determine the number, size, and distribution of wells that can be developed at a specific site. Long-range planning by the water suppliers to identify future wellfield sites, and to protect those future sites from contamination by controlling land use activities within the influence of the wellfield, is important in ensuring satisfactory future water supply.

Utility Interconnections

Interconnection of treated and/or raw water distribution systems between two or more utilities can provide a measure of backup water service in the event of disruption of a water source or treatment facility. Additionally, when considering future potable water needs, bulk purchase of treated water from neighboring utilities should be evaluated in lieu of expanding an existing source or treatment plant. A detailed study of distribution systems proposed for interconnection should address system pressures, physical layout of the supply mains, impacts on fire flows and compatibility of the treated waters.

Wastewater Reuse

Encouragement and promotion of wastewater reuse and water conservation are formal state objectives. The State Water Policy requires the FDEP and water management districts to advocate and direct the reuse of reclaimed water as an integral part of water management programs, rules, and plans. Several regulations also require an evaluation of reuse versus other disposal methods prior to issuance of Department permits.

Reuse is the deliberate application of reclaimed water for a beneficial purpose, in compliance with the Florida Department of Environmental Protection (FDEP) and water management district rules. Reclaimed water is wastewater that has received at least secondary treatment and is reused after flowing out of a wastewater treatment plant (Chapter 17-610, F.A.C.). Potential uses of reclaimed water include landscape and agricultural irrigation, ground water recharge, industrial uses, environmental enhancement and fire protection. Additional discussion of reuse, including reclaimed water regulations and more detailed information on potential uses, is provided in Appendix I.

Reuse Costs

The costs associated with implementation of a reuse program varies depending on the size of the reclamation facility, the facility equipment needed, the extent of the reclaimed water distribution system, and the regulatory requirements. The major construction components of a water reclamation facility and reclaimed water distribution system are:

- Filtration system with associated chemical feed facilities
- Disinfection system
- Continuous reclaimed water monitoring equipment for disinfectant residual and turbidity
- System mandated storage
- Reclaimed water pumping facility
- Reclaimed water distribution system

In addition to the varying equipment costs with size, the reclaimed water distribution system cost is also dependent on the area type (e.g., rural, suburban, and urban), and possible right-of-way acquisition. Operation and maintenance (O&M) costs must also be considered in the implementation of a reuse system.

Existing Treatment Facilities

Currently, there are 21 wastewater treatment facilities that have a FDER rated capacity of 0.50 MGD or greater in the LWC Planning Area. These facilities treated 42.76 MGD of wastewater in 1990. Of this, 16 facilities utilized reuse for disposal which accounted for 19.08 MGD. In addition to reuse, 0.08 MGD was disposed of by deep well injection and 22.60 MGD was disposed of by surface water discharge (see Figure II-5). This water that was disposed of by deep well injection or discharge to surface water could be made available with the addition of regulatory mandated equipment including filtration and the associated chemical feed system, disinfection facilities and reclaimed water monitoring equipment. The volume of wastewater is projected to increase to over 146 MGD by 2010. This summarized wastewater facility information, including the FDEP's antidegradation policy, is provided in detail in Appendix E.

Surface Water Storage

Surface water storage could be utilized by pumping surface water runoff and ground water seepage into regional storage systems during periods of excessive rainfall to provide additional water supply and flood protection. The capture of surface water runoff and ground water seepage in canals of the primary water management system, and storage of these waters in existing or new surface water reservoirs or impoundments, provides an opportunity to increase the supply of fresh water during subsequent dry periods. The primary problems associated with surface water storage are the expense of building and operating large capacity pumping facilities, the cost of land acquisition, appropriate treatment costs, the potential environmental impacts of discharging large volumes of polluted stormwater runoff, the availability of suitable storage locations, and the high evaporation rates of surface water bodies.

Aquifer Storage and Recovery (ASR)

Aquifer storage and recovery (ASR) is defined as the underground "storage" of injected water in an acceptable aquifer during times when water is available, and the subsequent "recovery" of this water when it is needed. Simply stated, the aquifer acts as an underground reservoir for the injected water, reducing the water loss to evaporation. Sources of injection water could include treated and untreated ground- and surface-water, and reclaimed water.

In the last few years, water utilities have been forced to face the realities of limited water resources, increasing demands, and more stringent water quality restrictions. Because of these limitations, ASR technology is receiving growing attention. The regulatory criteria for ASR permitting is discussed in Appendix I.

ASR Costs

Estimated project costs for ASR consisting of a 900-foot, 16-inch well, with two monitoring wells using treated water in Florida are shown in Table V-3. One system uses pressurized water from a utility; whereas the second ASR system uses unpressurized treated water, thus requiring pumping equipment as part of the system cost. Using the assumptions that the capital costs are amortized at 8 percent over 20 years, that the water recovery efficiency is 75 percent, and that the total water recovered in any year is 100 times the daily recovery capacity, the costs in Table V-3 translate into costs of $.23 to $.27 per thousand gallons. However, utilities implementing ASR systems may incur additional costs for surface facilities, such as piping, storage, and rechlorination. Other available data indicate that "typical unit costs for water utility ASR systems now in operation tend to range from $200,000 to $600,000 per mgd of recovery capacity" (CH2M Hill, 1993). At the same annual recovery rate used above (100 times the daily recovery capacity), the costs per thousand gallons recovered would be $.30 to $.70 per thousand gallons. These systems have well capacities in the range from .3 to 3 mgd and store treated water. Savings in treatment system costs are likely to be substantial when the ASR system offsets the need for capacity to meet peaks in demands.

TABLE V-3. Aquifer Storage and Recovery System Costs.

	Well Drilling Cost	Equipment Cost	Engineering Cost*	O&M Cost (per 1000 gal)	Energy Cost (per 1000 gal)
Treated Water at System Pressure	$200,000	$30,000	$360,000	$.004	$.06
Treated Water Requiring Pumping	$200,000	$100,000	$400,000	$.006	$.06

* Engineering costs include the permitting process, hydrogeologic investigation, monitoring during well construction, and design.

Source: PBS&J,Water Supply Cost Estimates, 1991.

Existing ASR Facilities

There are a number of ASR facilities in operation throughout the United States in New Jersey, Nevada, California, and Florida. ASR development studies are currently underway in Washington, Utah, Arizona, Georgia, South Carolina, Texas, and Virginia. Of these operational facilities, five are in Florida: Manatee County (1983), Peace River (1984), Cocoa (1987), Port Malabar (1989), and Boynton Beach (1993). These facilities all use treated water and are further discussed in Appendix I.

Evaluating a Potential ASR Project

In evaluating a potential aquifer storage and recovery program, eight major factors should be considered:

- Quantity and availability of injected water
- The quality of the injected water
- The amount of underground storage available in the aquifer, and at what depth
- The ability of the aquifer to accept and store the injected water and how readily can the water be recovered
- Impact of the injected water quality on the receiving aquifer
- Effect of the native water and the geologic formation on the stored water
- The reaction of the aquifer to chemical, physical and/or biological processes that may be introduced
- The amount of stored water that will be recoverable and its quality

Each potential ASR site must be assessed on its own merit from an economic as well as a technical point of view due to the large number of variables involved.

Advantages and Disadvantages

The following are potential advantages and disadvantages of ASR:

Advantages

- Small-scale land acquisition required, compared to surface water storage
- No loss of water to evaporation, as compared to surface water storage, where evaporation losses can be significant
- Ability to locate an ASR facility at the point of need
- Use of recovered water during the dry season does not adversely affect the surficial aquifer, water conservation, or wetlands
- Improved reliability of the utility system in the event of an emergency or drought

Disadvantages

- The quantity of water recovered may be less than the amount injected due to the degradation of the stored water over time
- Increased well maintenance may be needed - formation of deposits, which result from mixing of chemically dissimilar waters, is accelerated
- Initial start up cost for an ASR well is expensive compared to a surficial well - an ASR well requires greater depth and has more stringent well construction design criteria

Floridan Aquifer System (FAS)

The FAS yields only nonpotable water throughout most of the planning area. The quality of water in the FAS deteriorates, increasing in hardness and salinity to the south. Salinity also increases with depth, making the deeper producing zones less suitable for development than those near the top of the system. Despite the lack of potable water, developments in desalination technology have made treatment of water from the upper portion of the FAS feasible in the LWC Planning Area where chloride concentrations are not prohibitively high. Because of its depth and poor quality, few wells have penetrated the FAS in this area. Hydrogeologic data about the system are sparse. However, the system is areally persistent and normally displays hydrogeologic characteristics favorable to ASR development.

The cost of tapping the FAS in a given location would depend on a number of variables, including well construction, operation and maintenance, and water treatment. Cost estimates for drilling wells in the major aquifer systems of the LWC Planning Area are discussed in the "Wellfield Expansion" section. Treatment costs of desalination technologies (e.g., reverse osmosis and electrodialysis reversal) are discussed in the "Water Treatment Technologies" section.

Water quality varies throughout the upper portion of the FAS. Generally speaking, the two parameters of greatest concern for use by reverse osmosis and other water treatment technologies are total dissolved solids (TDS) and chloride. Common values for TDS in the upper portion of the FAS are 1,900 mg/L to 8,500 mg/L, chloride range from 1,000 mg/L to 2,000 mg/L. These values vary with depth and production zone.

Presently, the District has contracted for a detailed literature review and mapping of the upper portion of the FAS and its potential treatability by reverse osmosis. Recommendations for a range or amount of water available from the upper portion of the FAS cannot be made at this time due to lack of information. The U.S. Geological Survey information indicates that the major constraint on future development of the upper portion of the FAS is degradation of water quality rather than limited quantity. Upconing of deep saline water in some areas is important to consider in planning additional development in the upper portion of the FAS.

Seawater

Seawater averages about 3.5 percent dissolved salts, most of which is sodium chloride, with lesser amounts of magnesium and calcium. Seawater treatment systems are used successfully worldwide in areas with very limited freshwater supplies. In these areas, reverse osmosis and distillation are two treatment methods which have been used for conversion of seawater to fresh water. While seawater is plentiful and obtainable along the Gulf Coast, costs associated with the construction and operation of seawater reverse osmosis and distillation systems are very high. As with all surface waters, the ocean is also vulnerable to discharges or spills of pollutants which could impact a water treatment system.

Water Treatment Technologies

Lime Softening

Lime softening is used at 25 of the 29 water treatment facilities in the LWC Planning Area. Lime softening treatment systems are designed primarily to soften hard water, reduce color and to provide the necessary treatment and disinfection to ensure the protection of public health.

Lime Softening Process. Lime softening refers to the addition of lime to raw water to reduce water hardness. When lime is added to raw water, a chemical reaction occurs that reduces water hardness by precipitating calcium carbonate and magnesium hydroxide. Disinfectant may be added at several places in the treatment process, but adequate disinfectant residual and contact time must be provided prior to distribution to the consumer. The lime softening process is effective at reducing hardness, but is relatively ineffective at controlling contaminants such as chloride, nitrate, trihalomethane (THM) precursors and others (Hamann *et al.*, 1990).

Community public water supplies are required to provide adequate disinfection of the finished/treated water and to provide a disinfectant residual in the water distribution system. The use of free chlorine as a disinfectant often results in the formation of levels of trihalomethanes (THMs) that exceed the maximum contaminant level (MCL) of 0.10 mg/L. THMs are formed when free chlorine combines with naturally occurring humic materials in the raw water source.

Lime softening is ineffective in removing the chloride ion and only fairly effective at reducing total dissolved solids (TDS). Chloride levels of raw water sources expected to serve lime softening facilities should be below the chloride maximum contaminant level of 250 mg/L to avoid possible exceedences of the standard in the treated water. The current finished water TDS MCL is 500 mg/L. Concentrations above 500 mg/L in the treated water are acceptable so long as no other MCLs are exceeded.

Nitrate is not effectively removed by the lime softening process. Lime softening facilities with raw water sources with nitrate concentrations exceeding the MCL of 10 mg/L will probably require additional treatment to meet the standard.

Proposed Safe Drinking Water Act regulations for THMs and disinfection byproducts (DBPs) will require that many existing lime softening facilities modify their treatment processes to comply with the standards for these groups of compounds. Add-on treatment technologies that are effective at removing these compounds or preventing their formation include ozone disinfection, granular activated carbon (GAC), and air stripping.

Lime Softening Treatment Costs. Capital construction costs for lime treatment facilities tend to be similar to those of other treatment processes (Table V-4). Lime softening's cost advantages are in operating and maintenance expenses, where costs are typically 20 percent less than for comparable membrane technologies (see Table V-8). However, an increase in total hardness of the raw water source will require increased amounts of lime to maintain the same water quality. In addition, any free carbon dioxide present in the raw water must first be satisfied by the lime before any significant softening can occur, which will impact the costs associated with this treatment process.

TABLE V-4. Lime Softening Treatment Costs.

Facility Size (MGD)	Capital Cost ($ per gal/day capacity)	Engineering Cost ($ per gal/day capacity)	Land Require-ments (Acres)	O&M Cost ($ per 1000 gal)	Energy Cost ($ per 1000 gal)
3	$1.30	$.20	1.5	$.48	$.018
5	1.25	.19	2.5	.45	.018
10	1.22	.18	4.0	.40	.017
15	1.00	.15	6.0	.33	.016
20	.90	.13	8.0	.30	.016

Source: PBS&J, Water Supply Cost Estimates, 1991.

Reverse Osmosis

Reverse Osmosis (RO) technology has been used in Florida for a number of years. About 100 membrane treatment systems are operational in the state with a combined capacity of about 50 MGD. Major Florida public water supply RO facilities include Cape Coral, Venice, Sanibel, Englewood and Jupiter.

Reverse Osmosis Process. RO is a pressure-driven process that relies on forcing water molecules (feed water) through a semipermeable membrane to produce fresh water (product water). Dissolved salts and other molecules unable to pass through the membrane remain behind (concentrate or reject water). RO is capable of treating feed waters of up to 45,000 mg/L total dissolved solids (TDS) which approximates seawater. Most RO applications involve brackish water feed waters ranging from about 1,000 to 10,000 mg/L TDS. Transmembrane operating pressures vary considerably depending on TDS concentration (Table V-5). In addition to treating a wide range of salinities, RO is effective at rejecting naturally occurring and synthetic organic compounds, metals and microbiological contaminants. The molecular weight cutoff (MWC) determines the level of rejection of a membrane.

TABLE V-5. Reverse Osmosis Operating Pressure Ranges.

System	Transmembrane pressure operating range (psi)	Salinity TDS range (mg/L)	Recovery Rates (%)
Seawater	800-1500	10,000-50,000	15-55
Standard pressure	400-650	3,500-10,000	50-85
Low pressure	200-300	500-3500	50-85
Nanofiltration	45-150	Up to 500	75-90

Source: AWWA, Water Quality and Treatment, 1990.

Advantages of RO membrane treatment systems include their ability to reject organic compounds associated with formation of THMs and other disinfection by-products (DBPs), small space requirements, modular type construction and easy expansion. Disadvantages of RO systems include high capital cost, requirements for pretreatment and post-treatment systems, high corrosivity of the product water, and disposal of the reject.

Disposal of RO reject is regulated by the FDEP. Various disposal options include surface water, deep well injection, land application and reuse. Whether a disposal alternative is permittable depends on the characteristics of the facility and disposal site (letter dated December 12, 1990 from B.D. DeGrove, Point Source Evaluation Section, FDER, Tallahassee, FL).

Reverse Osmosis Costs. RO treatment and associated concentrate disposal costs for a typical South Florida system, (2,000 mg/L TDS, 400 PSI) are provided in tables V-6 and V-7. Variables unique to RO capital costs include system operating pressures and concentrate disposal, while variables unique to RO operations and maintenance costs include electrical power, chemical costs, membrane cleaning and replacement, and concentrate disposal.

TABLE V-6. Reverse Osmosis Treatment Costs.

Facility Size (MGD)	Capital Cost ($ per gal/day capacity)	Engineering Cost ($ per gal/day capacity)	Land Require-ments (Acres)	O&M Cost ($ per 1000 gal)	Energy Cost ($ per 1000 gal)
3	$1.40	$.21	.4	$.46	$.23
5	1.27	.19	.4	.43	.23
19	1.17	.18	.5	.41	.23
15	1.14	.17	.63	.40	.23
20	1.16	.16	.78	.30	.23

Source: PBS&J, Water Supply Cost Estimates, 1991.

TABLE V-7. Concentrate Disposal Costs.

Deep Well Disposal Facility (MGD)	Capital Cost ($ per gal/day capacity)	Engineering Cost ($ per gal/day capacity)	Land Requirements (Acres)	O&M Cost ($ per 1000 gal)
3	$.58	$.087	.5	$.032
5	.44	.066	.5	.024
10	.40	.060	1.0	.022
15	.37	.056	2.0	.02
20	.30	.045	3.0	.16

Source: PBS&J, Water Supply Cost Estimates, 1991.

Methods of determining capital and O&M costs vary from utility to utility, and as a result, cost comparisons of treatment processes can be difficult (Dykes and Conlin, 1989). Site-specific costs can vary significantly as a result of source water quality, reject disposal requirements, land costs, use of existing water treatment plant infrastructure, etc. Detailed cost analyses are necessary when considering construction of RO water treatment facilities. As a general rule, however, RO costs are 10 percent to 50 percent higher than conventional water treatment technologies.

Membrane Softening

Membrane softening or nanofiltration (NF) is an emerging technology that is currently in use in Florida. Membrane softening differs from standard RO systems in that the membrane has a higher MWC, lower operating pressures and feed water requirements of 500 mg/L or less of TDS. One significant advantage of membrane softening technology is its effectiveness at removing organics that function as THM and other DBP precursors. Given the direction of increasing federal and state regulation of drinking water quality, membrane softening seems to be a viable treatment option towards meeting future standards. A number of membrane softening facilities have been installed in Florida.

The costs associated with membrane softening are similar to those of reverse osmosis with operations and maintenance expenses tending to be lower because of higher energy rates and lower relative energy costs. Membrane softening treatment costs are presented in Table V-8.

TABLE V-8. Membrane Softening Treatment Costs.

Facility Size (MGD)	Capital Cost ($ per gal/day capacity)	Engineering Cost ($ per gal/day capacity)	Land Requirements (Acres)	O&M Cost ($ per 1000 gal)	Energy Cost ($ per 1000 gal)
3	$1.33	$.20	.4	$.44	$.159
5	1.21	.18	.4	.42	.159
10	1.12	.17	.5	.40	.159
15	1.10	.17	.63	.38	.159
20	1.06	.16	.78	.37	.159

Source: PBS&J, Water Supply Cost Estimates, 1991.

Electrodialysis and Electrodialysis Reversal

Electrodialysis (ED) is an electrochemical process that involves the movement of ions through anion- and cation- selective membranes from a less concentrated solution to a more concentrated solution by the application of direct electrical current. Electrodialysis reversal (EDR) is a similar process but provides for the reversing of the electrical current which causes a reversing in the direction of ion movement. ED and EDR are useful in desalting brackish water with TDS feedwater concentrations of up to 10,000 mg/L. ED/EDR, however, is generally not considered to be an efficient and cost-effective organic removal process and therefore is usually not considered for THM precursor removal applications (AWWA, 1988). Available cost data for ED/EDR is limited, but for the same area appear to be 5 to 10 percent higher than RO treatment (Boyle Engineering, 1989).

Distillation

The distillation treatment process is based on evaporation. Saltwater is boiled and the dissolved salts, which are non-volatile, remain behind. The water vapor is cooled and condenses into fresh water. Two distinct treatment processes are in use: multistage flash (MSF) distillation and multiple effect distillation (MED). Capital construction costs and operation and maintenance expenses are three to five times as expensive as more conventional processes such as brackish water RO systems and/or EDR (Buros, 1989).